

Manufacturing Advantage Service

Motherboard Damage Prevention

Intel Corporation
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Agenda

- Introduction
- Mechanical Damage Overview
 - Examples
 - Solutions
- Electrical Damage Overview
 - Electro-Static Damage (ESD) – Examples, Solutions
 - Electrical Over Stress (EOS) – Examples, Solutions
- BIOS Related Damage Overview
 - BIOS Corruption
 - CMOS Corruption
- Summary of Damage Prevention

Agenda

- **Introduction**
- Mechanical Damage Overview
- Electrical Damage Overview
- BIOS Related Damage Overview
- Summary of Damage Prevention

Introduction: Purpose

The purpose of this presentation is to:

- Define process induced damage as a problem.
- Illustrate the types of damage that can occur within a system manufacturing process.
- Share Intel's observations of induced damage.
- Offer solutions that can help a manufacturing site prevent the occurrence of process induced damage.
- Help Intel's desktop board customers save money by avoiding the costs associated with process induced damage.

Introduction: Problem Statement

Process Induced Damage costs the customer money:

- Replacement Costs
 - There are replacement costs for replacing motherboard (and/or other system components) that are damaged within the manufacturing process.
 - » Cost of debug time
 - » Cost of motherboard replacement time
 - » Cost of motherboard and/or other damaged system component
- Production Throughput
 - Damaged boards and components are not necessarily identified at the point where damage occurred.
 - It takes time and requires resources to troubleshoot a system and partially disassemble it in order to replace the damaged items.
 - Beat Rate: each damaged system requires additional time to get out the door.

Types of Process Induced Damage

While manufacturing with Intel® desktop boards, there are three types of damage that can be induced to the board.

- Mechanical Damage (some common examples)
 - Damage around screw holes from use of tools
 - Connector or Socket Damage from improper assembly/insertion
 - Damage around processor heatsink assembly
 - Component or Trace Damage during integration into chassis
 - Solder Connection Damage from flexing of board
- Electrical Damage
 - Electro-Static Discharge (ESD) Damage
 - Electrical OverStress (EOS) Damage
- BIOS Related Damage (corruption)
 - BIOS Corruption of FLASH programming
 - CMOS (BIOS Setup) Corruption

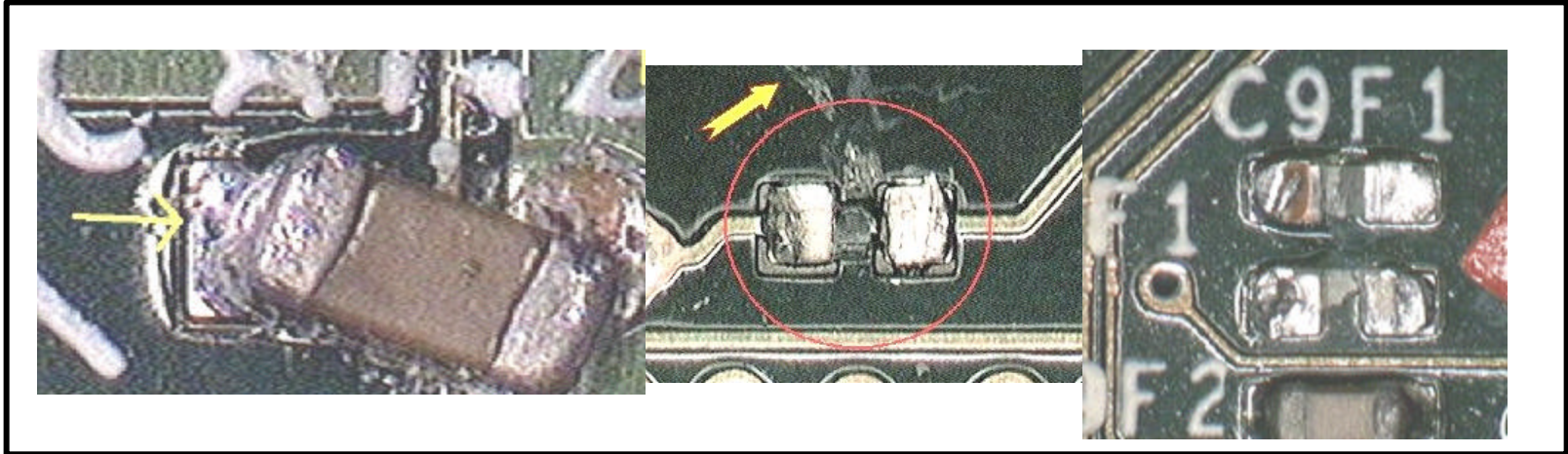
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 - **Examples**
 - **Solutions**
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Mechanical Damage: Problem Identification

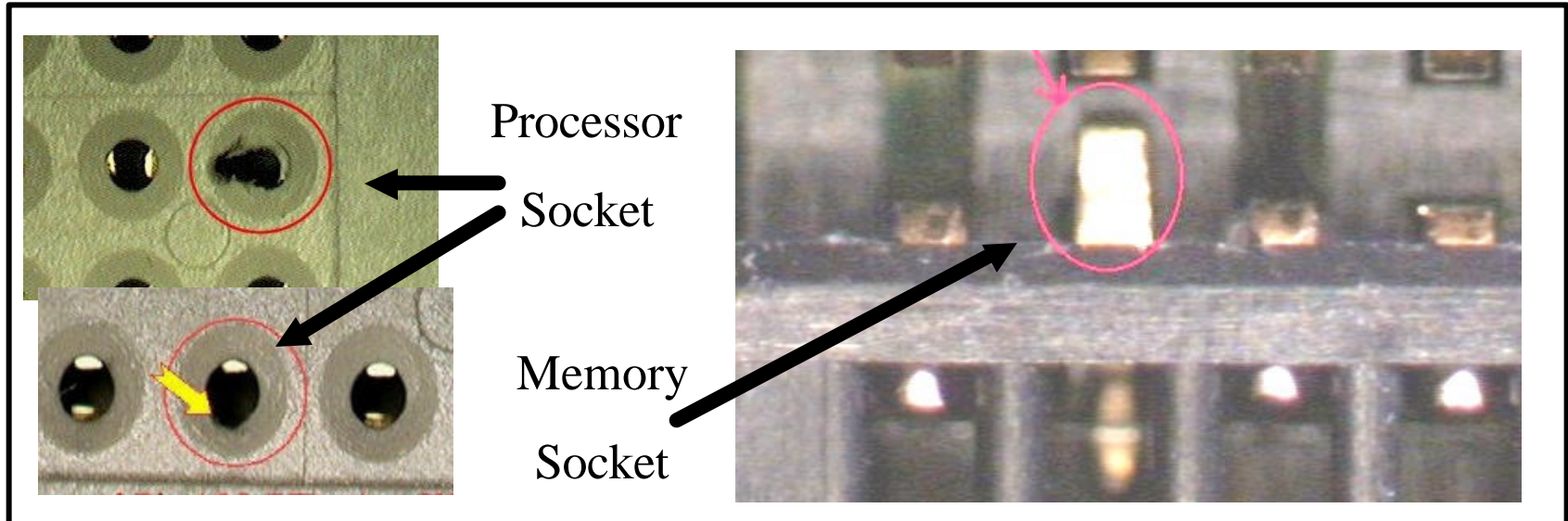
- As the motherboard passes through the system assembly process, some commonly occurring damage includes:
 - Damage around screw holes and other fastening points
 - » Screwdriver damage to components or traces around the hole
 - Connectors and sockets
 - » Damage to processor or memory sockets, add-in slots, cable connectors
 - Processor heatsink assembly
 - » Damage around socket while attaching or removing heatsink assembly
 - Trace damage
 - » Scratches to secondary side of board while assembling into chassis
 - Board flex damage
 - » Flexing causes stress to solder joints – especially large BGA components.
- Manufacturing technicians can decrease damage by continuous attention to the causes of defects found in the manufacturing environment.

Mechanical Examples: Screwdriver Damage



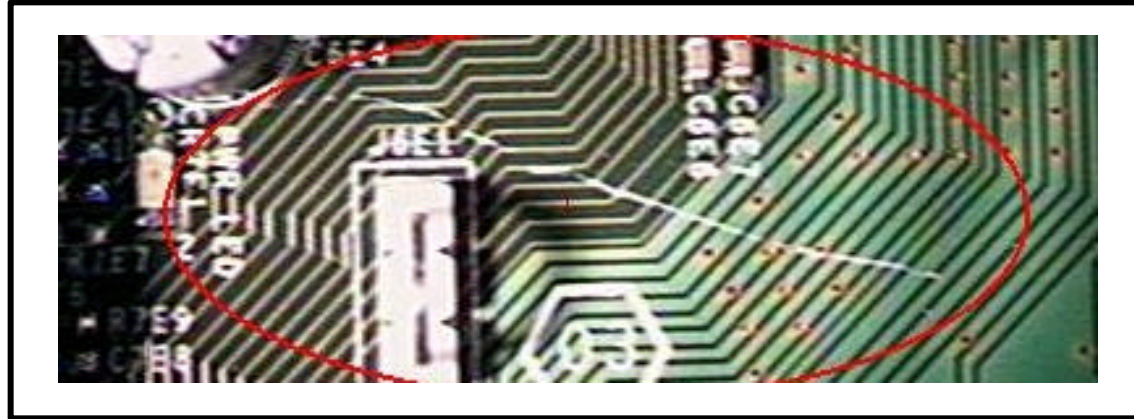
- Damage caused from screwdriver and other tools may appear
 - Around screw holes
 - » Often due to screwdriver slipping around motherboard mounting hole
 - Around processor heatsink assembly
 - » Often caused by slipping of tool used to attach heatsink assembly
- Consider the following
 - Driver tip
 - » Is it magnetized, and does it match screw heads?
 - Chassis design
 - » Are screw holes visible, and can attachments be made outside of chassis?

Mechanical Examples: Connectors & Sockets



- Processor socket damage
- Memory module socket damage
- Damage to PCI, AGP, and other slot connectors
- Pin damage to IDE/Floppy connectors
- Consider the following
 - Units oriented and aligned properly prior to insertion
 - Processor socket level fully open prior to insertion

Mechanical Examples: Trace Damage



- Trace Damage can be caused several ways
 - Tool damage around mounting holes
 - Tool damage around heatsink assembly
 - Secondary side (underneath motherboard) damage caused during integration of mother board into chassis
- Consider the following
 - Driver tip, method of integrating board into chassis

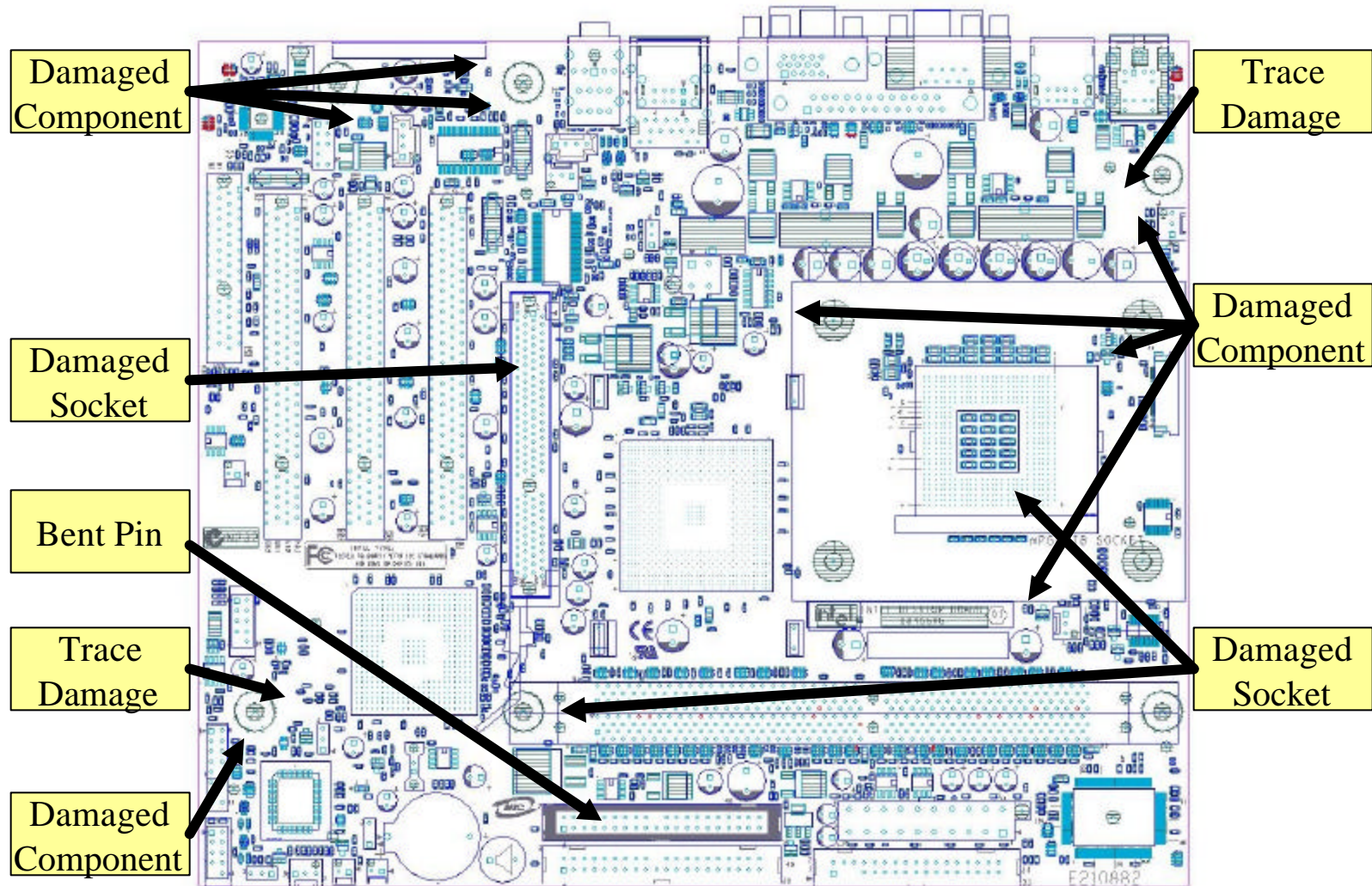
Mechanical Solutions

- **Analyze your failures to learn where your manufacturing process could be improved.**
 - Perform visual inspections of suspected failures.
 - Collect data on process induced damage
 - » Type of damage
 - » Location on board where damage occurred
 - Evaluate each manufacturing step to locate sources of potential mechanical damage.
 - » Audit
 - Analyze the data, pareto failures, to determine where improvements can be made.
 - » Manufacturing process changes
 - » Visual inspection points
 - Drive action for continuous improvement.

Mechanical Solutions: Mechanical Defect Analysis

- Tracking analysis of mechanical damage information can help to avoid future occurrences of inducing mechanical damage
 - **Damage data can be collected from detailed failure analysis**
 - **Data can also be collected from visual inspection results.**
 - **Defect Map (next slide) – a useful method to present defect data**
 - » The Defect Map is a method where locations and types of mechanical damage are mapped over a picture or diagram of a motherboard.
 - » The Defect Map provides a visual aid to board test and inspection areas and to system debug repair areas, to more quickly recognized previously occurring mechanical damage.
 - » The more upstream that defects are identified, the more feedback and awareness is present at the source where the damage is occurring.
 - **Reoccurrence of defects when captured, i.e. in Defect Maps**
 - » Define the top problem areas
 - » Identify areas for improvement
 - » Increase awareness of the top problem areas

Defect (CID) Map



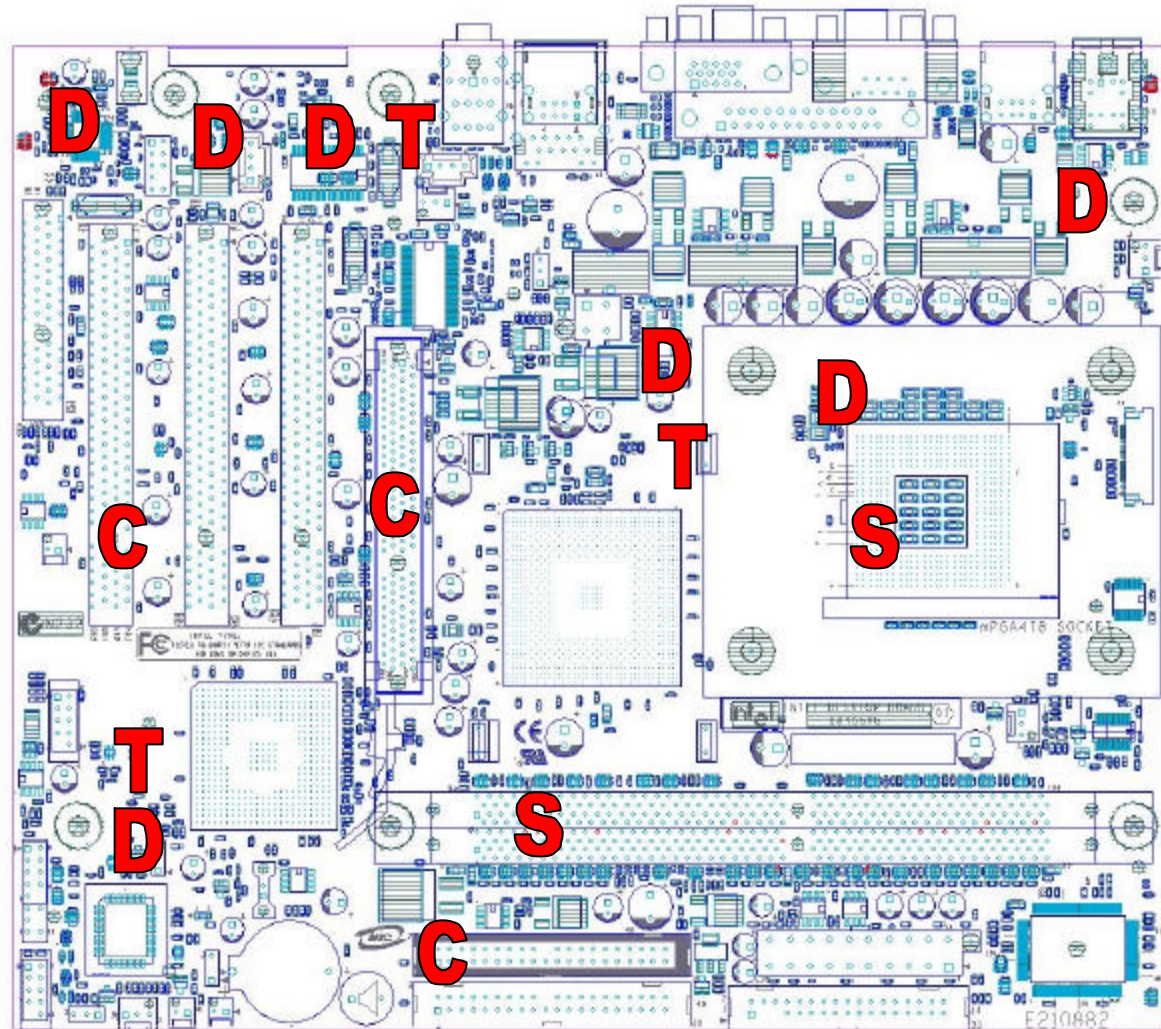
Defect (CID) Map

C Connector Damage

D Damaged Part

S Socket Damage

T Trace Damage



Mechanical Solutions: Point Inspection Process

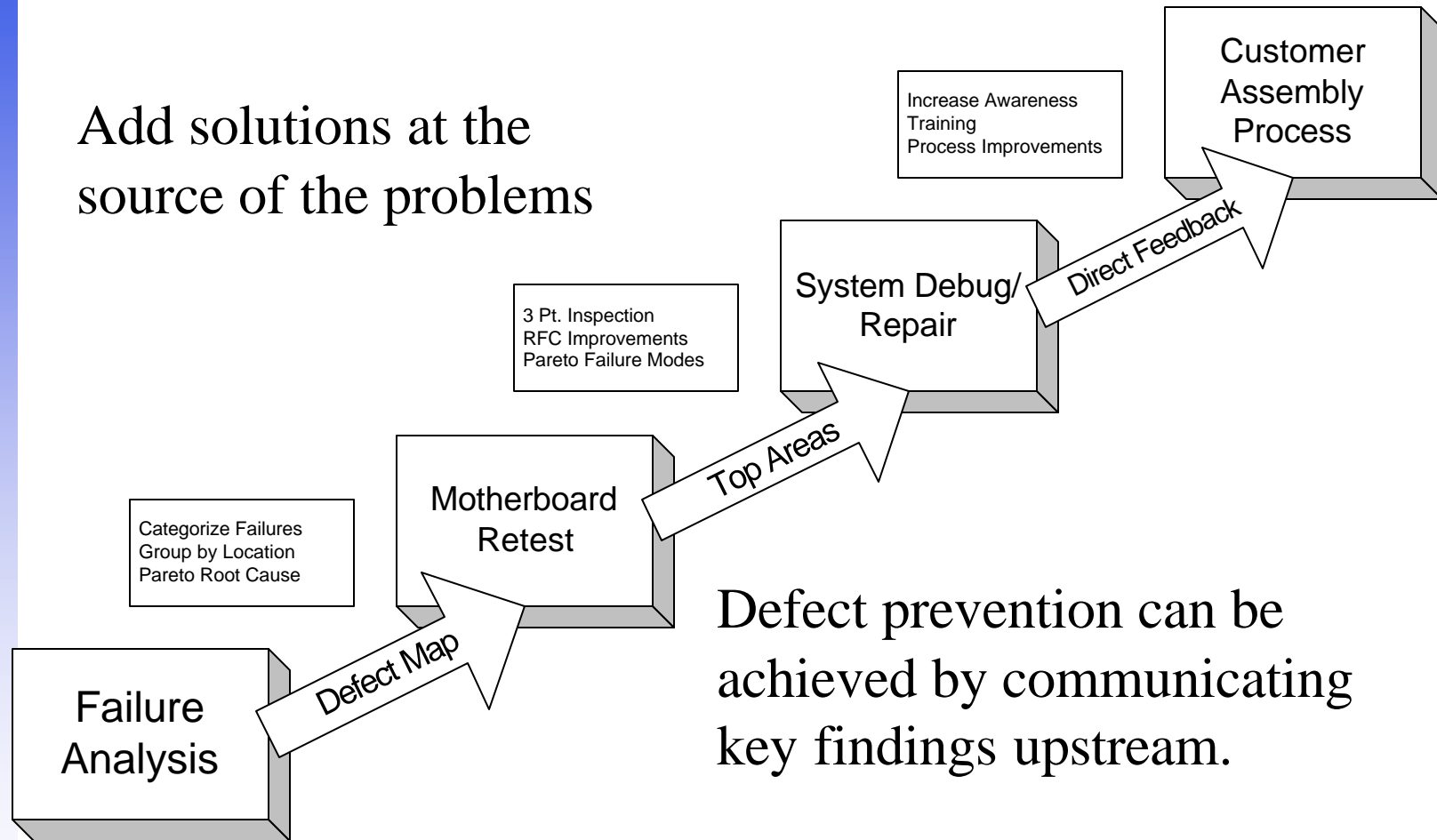
- **EXAMPLE: 3 Point Inspection Process**
 - Quick, effective, method of screening for damage around identified problems areas.
 - The example below is from a past study where the most common areas of damage were found to be around tooling holes, the processor socket, and the connectors.
 - Use of a 2X magnifying lamp may be advisable, if possible.
 - With this 30 second inspection process, customers have been able to verify as much as 90% of the mechanical induced defects.
 - **NOTE:** The number of points in the inspection, and which areas on the board should be inspected, should be determined by the data collected for defects found within the manufacturing process.
- **Point 1: Tooling Hole Inspection**
 - Check the area around all tooling holes for damage to components and traces nearby.
- **Point 2: Processor Heatsink Area Inspection**
 - Inspect around the processor socket for damaged traces and components caused by attachment or removal of the heatsink assembly and clip.
- **Point 3: Inspection for Connector Damage**
 - Check connectors for cracks, plugged holes and damaged pins as well as damage in surrounding area.



3 Point Inspection Process

Driving Process Improvement

Add solutions at the
source of the problems



Mechanical Damage Summary

- As motherboards pass through a given manufacturing process, there are certain problem areas where mechanical damage tends to be induced.
- Analyzing or visually inspecting damaged boards (in MRB) and collecting data (Defect Map) will identify the top problem areas.
- Watching for these identified problem areas (Point Inspection Process) within the process helps drive down damage in these areas by promoting increased awareness at the source.
- Periodically reviewing damaged boards, updating Defect Maps as needed, and continuing to utilize a Point Inspection Process, will drive continuous improvement towards the prevention of induced mechanical damage.

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- **Electrical Damage Overview**
 - **Electro-Static Damage (ESD) – Examples, Solutions**
 - **Electrical Over Stress (EOS) – Examples, Solutions**
- BIOS Related Damage Overview
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Preventing Electrical Damage

Electro Static Discharge (ESD) Damage

- Static electric charges come in contact with different static potential resulting in rapid movement of charge from one object to another, damaging devices in between
 - Improperly grounding worker or work surface
 - Insufficient ESD controls in manufacturing area
 - Presence of material susceptible to buildup of static charge

Electrical Over Stress (EOS) Damage

- Typically caused from electrical supply voltages such as power supplies or batteries
 - Hot Swapping devices
 - Unseated add-in or memory module causing shorts between pins
 - Foreign material causing shorts between pins or traces

Electrical Damage – ESD

- All electronic components can be damaged by ESD, producing failure throughout their life cycle
- Whenever there is movement static charge is produced
 - Static charge is always present
 - ESD caused by the rapid transfer of charge between two objects
 - » discharge from a person to a device
 - » discharge from a charged object to another object at a different potential
 - Static voltages (difference of potential) much less than what humans can see or feel can damage devices on the motherboard
 - » voltages less than 100v can damage devices
 - α This voltages becomes lower and lower with newer technologies
 - » we feel ESD at > 3000v
 - » we hear it at > 6000v
 - » we see it at > 8000v
- ESD Control Will
 - Reduce charge generation
 - Reduce potential differences between objects (Grounding)
 - Neutralize charges (Ionizers)
 - Remove field effects
 - Reduce inducing electrical damage caused by ESD events

7-Step Proposal of ESD Control

- Step 1 Audit your line for potential sources of ESD
- Step 2 Ascertain level of problem and amount of controls required
- Step 3 Establish a team to manage this activity
- Step 4 Develop a specification to ensure compliance
- Step 5 Built in the levels of controls required
- Step 6 Conduct regular audit
- Step 7 Ensure continuous training and improvements

ESD Control: Coordinator

- Procedure Writing
- Training
- Trouble shooting
- Advice, Reference, Documentation
- Assuring that audits are performed on a regular basis
- Leading ESD team
- Reporting areas needing improvement

ESD Control: Awareness and Training

- Applies to ALL
- All personnel made aware of the causes and effects of ESD
- All trained in handling and storage
 - New-hire training for work in controlled areas from raw material warehouse to packaging, including material handlers, auditors, debug/repair technicians, maintenance etc.
 - Documentation and training available for non-manufacturing personnel that visit ESD controlled areas
- Visitors catered for
 - ESD controlled areas defined, marked, and labeled
- Susceptible areas need controlled access

ESD Control: Program Requirements

PRIMARY CONTROL

- * Conductive/antistatic packaging
- * Grounded workstation
- * Grounded wrist strap
- * Conductive smock
- * Processing equipment < 200V
- * Dissipative indirect materials
- * Faraday shielding storage

SECONDARY CONTROL

- * Humidity control >40%
- * Warning signs/labels
- * Ceiling ionizes
- * Conductive flooring
- * Conductive curtain
- * Training
- * Procedures / Documentation

ESD Control: Indirect Material

- Original packing can be an ESD hazard
 - Loose fill polystyrene / bubble wrap
 - Styrofoam
 - Clingfilm
 - Plastics
 - Paper
 - Tape
- Storage
 - Stored in protective containers
 - » Bags
 - » Boxes
 - » Trays
- Transportation
 - Carts
 - Racks

ESD Control: Indirect Material

- In-house movement
 - Closed conductive containers (Faraday shield)
 - Only open at approved areas
 - Label approves areas
- Shipment
 - Shielded containers
 - Well labeled
 - Beware of cushioning material (foams etc..)

7-Step Proposal of ESD Control

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EOS Control: Work Procedures

- Documented test/assembly flows
- Correct insertion of devices - use pictorial reminders
- Beware of powered insertions and removals
 - Never hot swap devices
 - » Hot swapping refers to adding/removing devices with power on
 - » Hot swapping causes current spikes that can often damage devices
 - Promote awareness of stand-by power
 - » Power can be present on the motherboard when it appears to be off
 - » Adding/removing devices with stand-by power on can damage devices and the motherboard
 - Remove AC power when adding/removing devices to the system
- Check connections
 - Cable connections, add-in card insertions, memory, processor, etc.
- Battery
 - Avoid touching battery during assembly

EOS Control: Maintenance / Line Monitoring

- Equipment not grounded
- Loose connections causing intermittent events
- Poor wire management
- No AC line monitoring.

EOS Control: Board Test and Debug/Repair

- Test and Debug areas need to avoid
 - Hot swapping
 - Incorrect test sequence
 - Foreign material on board or in connectors
- Between steps to add, remove, or exchange parts assure AC power removed for enough time to dissipate all power from motherboard
 - Assembly – connect AC last
 - Disassembly – disconnect AC first
- Probing (test equipment)
 - Assure probes placement is precise
 - » Avoid causing shorts
- Battery
 - Avoid touching battery
 - » Shorting top (+) to board can caused EOS damage to board

Preventative Programs

- ESD Control
 - 7-step proposal
 - Coordinator or group focus
 - Awareness and training
 - Ground straps
 - Work stations/ Controlled areas
 - Clothing
 - Indirect materials
- EOS Control
 - Work procedures
 - Cable maintenance
 - Maintenance / line monitoring
 - Board / component testing
 - System Debug/Repair

Electrical Damage Summary

- ESD
 - Static voltage much less than what humans can see or feel can damage devices
 - Electrical charge is everywhere
 - ESD Controls need to be defined and enforced to avoid ESD damage
 - » All persons must support ESD controls
 - » All persons need to be aware and need to be trained
- EOS
 - Beware of powered insertions and removals
 - » Never hot-swap devices
 - » Be aware of stand-by power
 - Check connection
 - Ensure good maintenance controls are in place
 - » Equipment grounded
 - » Good AC line monitoring

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- **BIOS Related Damage Overview**
 - BIOS Corruption
 - CMOS Corruption
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BIOS Introduction: Purpose

- To define and scope BIOS and CMOS corruption as a problem
- To communicate practical actions that can be taken on the production line to minimize the problem
- To identify appropriate tools to help you prevent BIOS corruption

BIOS Introduction: So What Is the Problem?

- 100's of BIOS Corruption Devices Analyzed with $<0.1\%$ Hard Component Failure (except ESD/EOS)
- World Wide Flash component DPM < 100
- BIOS corruption is significantly higher than 100 DPM!
 - This CID (Customer-Induced Defect) problem is the corruption of the contents in the Flash device.
 - » BIOS Corruption causes include
 - ⌘ Process interrupted during BIOS reflash
 - ⌘ Network interference during reflash over network
 - ⌘ Bad floppy diskettes used for floppy-based reflash
 - ⌘ Bad AC power at reflash station

Detecting BIOS Corruption

- Prevention begins with awareness
 - Often BIOS corruption can go undetected and is mistaken for a defective motherboard.
 - Detecting BIOS corruption at system debug brings awareness AND avoids the extra time and expense of unnecessarily replacing an otherwise good motherboard.
 - » Whenever a failing system demonstrates a fail signature consistent with BIOS corruption, it is advisable that a BIOS recovery is attempted.
 - » If the failure signature no longer persists then it can be assumed that there was BIOS corruption and that it has been corrected.
 - ⌘ NOTE: After a successful recovery the system should return to the beginning of the test process to guard against intermittent failures.
 - ⌘ NOTE: Care should be given to assure that the correct BIOS is used during a BIOS recovery attempt

BIOS Corruption Identification at System Debug

- Signatures
 - No video, no speaker beeps, or no port 80 activity (POST failure)
 - System locks-up during boot/power-on process
- Possible Causes
 - Corrupted BIOS code in main flash
 - Other
- If cause is BIOS corruption, time and money can be saved by attempting a BIOS recovery prior to removing or replacing the motherboard

BIOS Reflash vs. Recovery

- Reflash
 - Performed to change from one BIOS revision to another
 - Recommendation to be automated within production to help avoid possible BIOS corruption to the motherboard
 - Uses Intel iFLASH or Intel Express BIOS utility
- Recovery
 - Performed to clear and re-program BIOS in a non-functioning motherboard
 - Used to detect and correct BIOS corruption
 - Used with iFLASH utility from a floppy diskette
 - » See procedure – next slide

BIOS Recovery BKM

- With system power off, remove the configuration jumper from the motherboard
- Insert correct iFLASH diskette into the floppy drive
 - You cannot use an iFLASH diskette intended for a different motherboard family
 - You can use an iFLASH with a different BIOS revision level, but you will need to subsequently reflash to the desired BIOS revision.
- Power system on
 - There will be one long beep (meaning floppy found)
 - Floppy LED light will come on
- Wait for two long beeps and floppy LED to go off
 - **Powering system off too early will result in BIOS corruption**
- Power system off and replace jumper (pin 1,2)

BIOS Solutions: Customer

- Do not interrupt power during Reflash or Recovery process
- Don't Use Floppy Disks for Reflash Procedures, if possible
 - Automate reflash over local network
- Use Intel® BIOS Utilities (Intel® iFLASH BIOS Update, or Intel Express BIOS Update)
- Isolate and/or filter AC lines at Reflash Stations
- Use Highest Quality DC Power supplies for Reflash Stations
- No hot-plugging of PC peripherals during reflash or system test
 - e.g. operators connecting up serial port ready for next test
- Develop Good Failure Verification Procedures
- Use ESD Precautions at Reflash Stations
- Develop Good BIOS Corruption Containment Procedures

CMOS Corruption

- CMOS, a part of BIOS, is where key system configuration parameters are stored, including BIOS (Setup) settings and the Real Time Clock setting
- CMOS Corruptions has a variety of possible signatures
 - No video, no speaker beeps, or no port 80 activity
 - System locks-up during boot/power-on process
 - Devices not recognized or not working properly
 - Date/Time not set (lost date/time settings)
 - NVRAM checksum or data invalid error

CMOS Corruption (cont.)

- Correcting CMOS Corruption
 - Method 1: BIOS Setup
 - » Not an option for some types of failures, (i.e. POST failures)
 - » Enter BIOS Setup and reset configuration settings
 - To reset default settings with Intel most standard BIOS
 - Press [F2] during power-on (after memory test, before OS boot)
 - Press [F9] to set default, press [F10] to save and exit Setup
 - Consult Technical Product Spec for specific key assignments
 - Method 2: Remove battery
 - » May not be suitable for high-volume manufacturing due to the possibility of inducing mechanical damage while removing/replacing battery w/ tool
 - » Clear CMOS
 - Remove CMOS battery from motherboard
 - Wait at least 20 seconds, replace battery
 - Method 3: BIOS Recovery
 - » This will make it impossible to tell the difference between BIOS Corruption vs. CMOS Corruption
 - » Perform BIOS Recovery (see Best Known Method on prior slide)

CMOS Corruption (cont.)

- Possible causes of CMOS Corruption
 - CMOS battery
 - » If the CMOS battery is shorted or removed during system integration, CMOS memory can be lost, causing corruption
 - » Care should be given not to touch the battery at assembly
 - Interruption of test process
 - » If the CMOS is programmed during functional test, and the system is powered off during this process, corruption may result
 - » When CMOS program utilities are used in functional test, the system should complete test before being powered off
 - Incorrect BIOS Setup settings
 - » If BIOS Setup is performed manually, incorrect setting can result in functional failure
 - » Steps should be in place to assure correct settings in Setup

BIOS and CMOS Summary

- We have seen that BIOS Corruption is often a major contributor to production line fallout
- Solutions to prevent this problem have been defined
 - BIOS Recovery
 - » Repairs a motherboard with BIOS Corruption
 - » Avoids removal of an otherwise good motherboard
 - » Identifies the failure was due to BIOS (or CMOS) Corruption
 - » Tracking where and how often BIOS Corruption is identified through BIOS Recovery is the first step towards evaluating where and how the corruption is occurring.
- In order to determine if a CMOS Corruption problem is contributing towards an overall BIOS Corruption problem, consider resetting or clearing CMOS before BIOS Recovery.
 - Most of CMOS is cleared as a result of a BIOS Recovery

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- **Summary of Damage Prevention**

Summary

- Customer Induced Damage costs the customer money.
- Damage comes in three categories
 - Mechanical, Electrical, and BIOS Related
- Identifying and tracking induced damage helps to prevent it
 - The further “upstream” it’s identified, the closer to the source.
 - Identifying the source lead to prevention
- Mechanical
 - Defect Maps are a useful method to track the occurrence of damage
 - » Defect Maps further enhance the Point Inspection process
 - Point Inspection method is useful for identifying mechanical defects

Summary (cont.)

- Electrical
 - ESD (Electro-Static Discharge)
 - » Static voltages, much less than what humans can see or feel, can damage motherboards and other devices
 - » Electric charge is everywhere
 - All persons must support ESD controls
 - Employees need to be aware and need to be trained
 - EOS (Electrical OverStress)
 - » Avoid hot swapping
 - » Beware of stand-by voltages present on motherboard when adding or removing devices to/from the system.
- BIOS/CMOS Corruption
 - BIOS Recovery

Backup

ESD Control: Ground Straps

- Wrist straps
 - Good fitting
 - Quick release connecting lead
 - Conductive surface in contact with skin
 - No conductors accessible on outside.
 - Continuous monitors or scheduled checks
- Shoes and Footstraps
 - Allows mobility
 - Floors must be grounded, static dissipative floor or mats
 - Should be both feet
 - Should be multi point contact
 - Direct contact made to skin or through hosiery

ESD Control: Work Stations and Areas

- Floors/mats
 - Dissipative or conductive material connected to ground
 - In conjunction with conductive footwear or conductors on carts and trolleys
 - Decay potential of 5000v to 50v
- Chairs
 - Made of or covered with conductive or dissipative material (backs, seats ,arms)
 - All three parts connected to at least one foot of chair

ESD Control: Work Stations and Areas

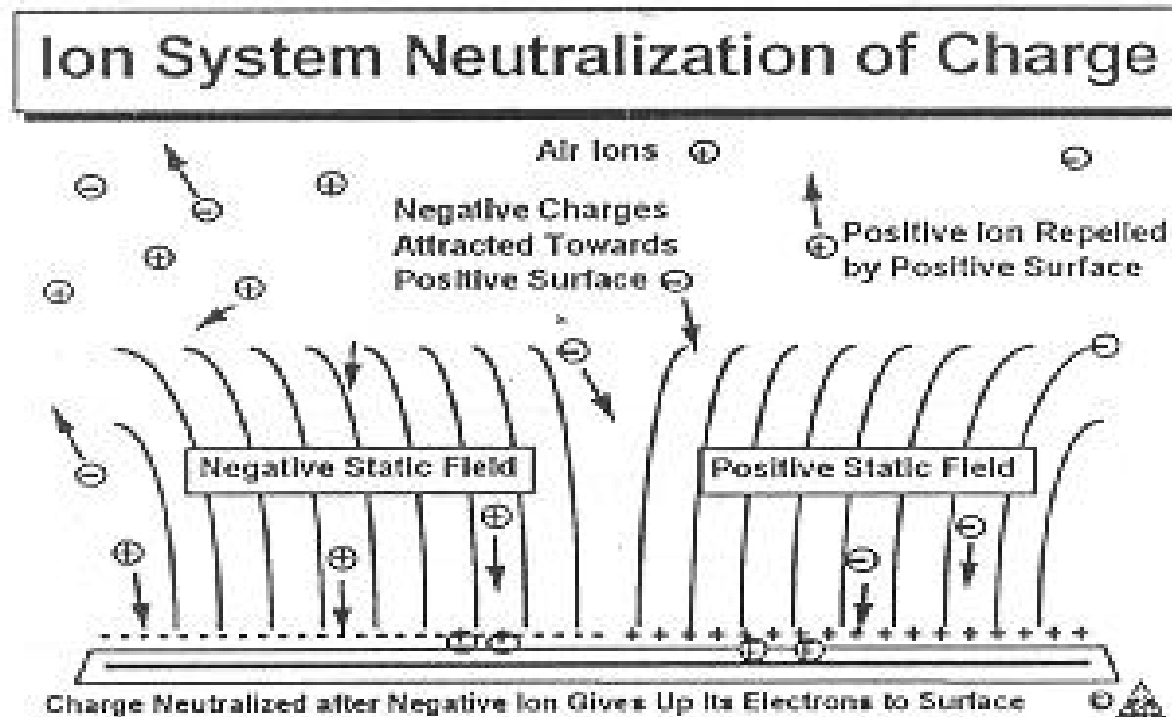
- Work Surfaces
 - Must be able to remove charge from protective package in controlled manner
 - Potential decay from 5kv to 50v
 - Must not retain charge
- Humidity
 - Low humidity severely reduces dissipative properties of materials.
 - Excessive humidity can cause corrosion and possible leakage paths of high voltages.

ESD Control: Work Stations and Areas

- Air Ionization
 - Not an alternative to other methods
 - Used when additional requirements are identified
- Earthing and Grounding
 - All areas must have ESD earth or ground facility
 - Must be reliable
 - Must be regularly checked
 - Should not have transient voltages which could affect equipment or personnel
 - Easily accessible and labeled
 - Ground fault monitors/fail safes

ESD Control: Work Stations and Areas: Ionizer

- Ceiling ionize, ionize blower
- Generate +ve and -ve ions to neutralize surface charges



ESD Control: Work Stations and Areas

- Vacuum Nozzles
 - In direct contact with device so should not generate or hold charge
 - Often overlooked
- Monitor Screens
 - CRTs, TVs and computer monitors may need special screen covers or treating
- Paperwork and Folders
 - Major source of potential static charge generation

ESD Control: Work Stations and Areas

- Bin liners
 - Keep away from immediate components
 - Always empty away from area
- Solvent bottles and containers
 - Can generate charge if common plastic or non static safe material
 - Use dissipative sleeves or bottles
 - Ensure sleeves are safe for contents
- Identification of areas and equipment
 - Clearly label area
 - Clearly label workstations and materials
 - Set expectations
 - ALL to enforce

ESD Control: Clothing

- Added protection of coats and jackets
 - Protects from charges built up on clothing
- Gloves or finger covers
 - Often needed when body oils is a concern

Appendix 1: Printed Collateral

- Intel® Flash Memory Handbook
 - » Intel Literature Number (2 Book Set) 210830
- or
- www.intel.com
 - » <http://developer.intel.com/design/flcomp/>
- Specific references:
 - AP-636: Preventing BIOS Failures Using Intel's Boot Block Flash Memory
 - AP-608: Implementing a Plug and Play BIOS Using Intel's Boot Block Flash
 - AP-610: Flash Memory In-System Code and Data Update Techniques